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(71) Sökande *Volvo Aero Corp, Trollhättan SE*
Applicant (s)

(21) Patentansökningsnummer *0100079-3*
Patent application number

(86) Ingivningsdatum *2001-01-11*
Date of filing

Stockholm, 2003-07-24

För Patent- och registreringsverket
For the Patent- and Registration Office

Juris Rozitis

Avgift
Fee *170:-*

PATENT- OCH REGISTRERINGSVERKET
SWEDEN
Postadress/Adress Box 5055 S-102 42 STOCKHOLM
Telefon/Phone +46 8 782 25 00 Vx 08-782 25 00
Telex 17978 PATOREG S
Telefax +46 8 666 02 86 08-666 02 86

Ink. t. Patent- och reg.verket
2001 -01- 1 1
Huvudfaxen Kassan

C.13539/KS, 2001-01-09

Title:
Rocket engines

TECHNICAL FIELD

The present invention relates to a rocket engine member according to the preamble of the subsequent claim 1.

BACKGROUND OF THE INVENTION

During operation, a rocket combustion chamber or a rocket engine nozzle is subjected to very high stresses, for example in the form of a very high temperature on its inside (in the order of magnitude of 800 °K) and a very low temperature on its outside (in the order of magnitude of 50 °K). As a result of this high thermal load, stringent requirements are placed upon the choice of material, design and manufacture of the outlet nozzle. At least there is a need for effective cooling of the combustion chamber or the outlet nozzle.

Its a problem to construct cooled wall structures that are capable of containing and accelerating the hot exhaust gas and that are able to do this in a reliable way for a large number of operation cycles. The present solutions do not have a sufficient long service life required for a large number of operation cycles. The present systems generate large thermal stresses, include large pressure drops or present difficulties when needing repair.

When applying the expander engine cycle, there is a secondary problem. The expander engine cycle uses the

cooling m dium to drive the turbin s in the fuel and oxidator turbo pumps, i.e. energy from the expansion of the heated cooling medium is used for driving the turbines. The efficiency of the rocket engine is a function of the combustion pressure. To reach high pressure in the expander cycle, efficient heat transfer from the exhaust gas to the cooling medium is required. Increase in the heat load in the combustion chamber due to surface roughness or fins may impair the service life of the engine since the intensity of the heat load is very high in the combustion chamber. A longer combustion chamber increases the length of the engine and the rocket. Increasing the size of the nozzle leads to large nozzles and increased length of the rocket structure, which increases the weight of the vehicle.

There are several different prior art methods for manufacturing a rocket nozzle with cooling channels. According to one of these methods, the nozzle has a brazed tube wall. The tubes have a varying cross section width to provide the contour of the nozzle when assembled. The variation in cross section is given by variation of the circumference and by variation of the form of the cross section. The brazed joints restrict the deformation of tubes in the thermal expansion and pressure cycle. The stresses in the tubes are increased in the arc of the joints. The joints themselves are weak points that may break and are difficult to repair. The brazed tube wall provides a larger "wet" contact surface for the rocket flame than a sandwich wall or a constant tube section wall. However, an even larger wet surface would be desirable.

According to another prior art method, a s ndwich wall is made by milling channels in sheet metal and joining a thinner sheet metal to seal the channels. The inner and outer walls are continuous shells. In the thermal cycle the walls are in compressive and tension strain. This type of wall structure is not well suited to sustain the tension loads normal in the service life of a rocket nozzle. The sandwich wall features no increase in surface area to enhance heat transfer.

According to still another prior art method, the nozzle wall is manufactured with constant section tubes. The tubes are helically wound and welded together to form the nozzle contour. The increase in surface area is small. The tubes have an angle relative the flow. This helps to increase the heat transfer. However, at the same time the exhaust flow is rotated and a reactive roll momentum influences the flight of the rocket. The constant section tubes result in a large pressure drop that is not favorable for convectively cooled engines. The large pressure drop is negative for the expander cycle type engine.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved method for manufacturing a cooled rocket engine member.

This is achieved by means of the rocket engine member according to the invention, which is characterized in that the outside of the wall structure includes a continuos sheet metal wall, and that the cooling channels

are longitudinally attached to the inside of the sheet metal wall.

As a result of the invention, a rocket engine member may be manufactured which presents high pressure capacity, a low pressure drop, a long cyclic life as well as advantageous area ratio. The manufacturing lead time and cost may also be optimized.

Advantageous embodiments of the invention can be derived from the subsequent contingent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in the following, in a non-limiting way with reference to the accompanying drawings in which:

FIG 1 is a schematic side view showing a nozzle according to the invention,

FIG 2 is a partial sectional view along the line A-A in Fig. 1, showing three cooling channels at the inlet end of the nozzle, according to a first embodiment of the invention,

FIG 3 is a similar view as Fig. 2, showing two of the cooling channels along the line B-B at the outlet end of the nozzle,

FIG 4 is a partial sectional view along the line A-A in Fig. 1, showing two cooling channels at the inlet end of the nozzle, according to a second embodiment of the invention,

FIG 5 is a similar view as Fig. 4, showing the cooling channels along the line B-B at the outlet end of the nozzle,

FIG 6 is a similar view as Fig. 5 showing a variation of the invention,

FIG 7 is a partial sectional view along the line A-A in Fig. 1, showing cooling channels at the inlet end of the nozzle, according to a third embodiment of the invention, and

FIG 8 is a similar view as Fig. 7, showing the cooling channels along the line B-B at the outlet end of the nozzle.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a diagrammatic and somewhat simplified side view of an outlet nozzle 10 that is produced according to the present invention. The nozzle is intended for use in rocket engines of the type using liquid fuel, for example liquid hydrogen. The working of such a rocket engine is previously known per se and is therefore not described in detail here. The nozzle 10 is cooled with the aid of a cooling medium that is preferably also used as fuel in the particular rocket engine. The invention is however not limited to rocket engine members of this type but can also be used in combustion chambers and in those cases in which the cooling medium is dumped after it has been used for cooling.

The outlet nozzle is manufactured with an outer shape that is substantially bell-shaped. Thus, the nozzle 10 forms a body of revolution having an axis of revolution and a cross section that varies in diameter along said axis.

The nozzle wall is a structure comprising a plurality of mutually adjacent, tubular cooling channels 11 extending substantially in parallel to the longitudinal axis of the

nozzle from the inlet end 12 of the nozzle to its outlet end 13. The outside of the structure includes a continuous sheet metal wall 14. The tubular cooling channels 11 are curved in the longitudinal direction to conform to the nozzle contour and they oriented axially along the nozzle wall, in this position, they are jointed to the metal wall by welding. The welds are preferably made by laser welding from the outside. This assembly forms a leak tight nozzle with all joints at the cool side of the structure.

The cooling channels 11 in the embodiment according to Fig. 2 and 3 are circular tubes 15 having a varying cross section. The tubes 15 may be seamless and have a smaller cross section at the inlet end 12 of the nozzle than at the opposite end.

The cooling tubes 15 are mounted without mutual gaps. At the inlet end of the nozzle, the thickness of the tube material is thin to minimize the maximum temperature and to allow the tubes to be flexible to deformation of the cross section. At the outlet end 13 of the nozzle, the tubes have a larger cross section as well as a thicker tube material. This variation in material thickness allows the tubes to adapt to increased pressure inside the tubes when the cooling medium expands. At the inlet, the tubes may be formed to oval shape to increase the number of tubes.

The variations in tube cross section and tube material thickness are gradual in the longitudinal direction of the nozzle.

Figures 4 and 5 show a second embodiment of the invention that is adapted for enhanced heat pickup. The cooling tubes 15 are manufactured with a constant material thickness and a gradually increasing diameter. The tubes have a smaller cross section at the inlet end 12 of the nozzle than at the opposite end. The inlet ends of the tubes have machined faces to allow a small pitch at this end of the nozzle to enable large area ratios. The cooling tubes are mounted without mutual gaps at the inlet end of the nozzle where the flame pressure and heat load is at its highest value.

At the outlet end 13 of the nozzle, the tubes 15 are separated in the tangential direction. A cavity 16 is formed between each pair of tubes 15 and the sheet metal wall 14. The gap between the tubes allows the hot rocket flame to access the cavity and thus more tube surface for enhanced heat pick up. Also, by allowing a gap between each pair of adjacent tubes, the tube may be conical and yet be acceptable to fit a bell shaped nozzle. The variation in cavity width between two adjacent tubes are gradual in the longitudinal direction of the nozzle.

With the nozzle design described above, the amount of heat transferred to the coolant in the nozzle may increase by a factor of 1.5. It is assumed that the cooling surfaces outside the widest part of the tube are effective only by a factor of 0.5. It is further assumed that only half the length of the nozzle structure has enlarged surface since the gap between the tubes is not present at the inlet end of the tube.

In cases where the heat load is high at the exit of the nozzle, the design shown in Fig. 6 makes it possible to protect the sheet metal wall 14 from the heat load. Thus, the cooling cavity may be filled with a thermally insulating material 17 to prevent the gas from contact with the load carrying outer shell so that the material temperature is limited. Alternatively, the walls may be coated with a thermally conductive material 17 for increased heat transfer to the cooling tubes. In a case where the conductive material, e.g. copper, completely fills the cavity, it is possible to reach very high pressures and high area ratios. The process to apply the conductive material may be brazing or laser sintering.

Figures 7 and 8 show a fourth embodiment of the invention where U-formed profiles 18 are used instead of the above described circular tubes 15. The profiles have a varying cross section and a varying material thickness. The profiles are manufactured by press forming sheet metal strips. The variation in thickness is adapted to the length of the nozzle. Thus, the material thickness may increase when the cooling channel cross section is increased, so that the thickness is small at the inlet end of the nozzle where the heat load is high. It is preferable to modify the metal strip thickness before folding. The structure in figures 7 and 8 has been combined with the thermally insulating/conductive material 17.

It is possible to build the structures described above from the common materials for rocket engine nozzle tubes such as stainless steel and nickel based alloys. Also copper and aluminum are suitable materials.

One of the important advantages of the wall structure according to the invention is that it offers a large cooling surface for increased heat absorption. The variations in cross section and tube material thickness allows for high internal pressure in the cooling channels 11. The increased wet surface in the nozzle structure according to the invention cools the boundary layer more than at a conventional nozzle. The boundary layer leaving the rocket nozzle will be cooler. The cooler boundary layer serves as cooling film for an eventual radiation cooled nozzle extension that may be used as a low cost solution when the heat load is limited. The nozzle extension could be less costly since the heat load is limited.

The rotational symmetric outer surface of the nozzle structure according to the invention provides stiffness itself and, if necessary, allows for attachment of stiffeners in an easy way. The single joint to the sheet metal wall isolates jackets and allow the tubes to be flexible to thermal distortion while implying a minimum of stress concentration. The cross section of the cooling channels may be close to circular. This means that the temperature differences and associated stresses are lower than compared to sandwich walls, where the flame is not in contact with the outer wall. The gap 16 between the tubes eliminates the restriction on cooling channel dimensions to form the nozzle contour. The cooling channels or tubes could be made with liner variation, which offers advantages in manufacturing.

The invention is not limited to the above-described embodiments, but several modifications are possible within the scope of the following claims.

C.13539, 2001-01-09

CLAIMS

1. A liquid fuel rocket engine member (10) forming a body of revolution having an axis of revolution and a cross section which varies in diameter along said axis, and having a wall structure comprising a plurality of cooling channels (11),
c h a r a c t e r i z e d in
that the outside of the wall structure includes a continuos sheet metal wall (14), and
that the cooling channels (11) are longitudinally attached to the inside of the sheet metal wall.

2. A member according to claim 1,
c h a r a c t e r i z e d in
that the cross sectional area of each cooling channel (11) is larger in a downstream end (13) of the channel than in an upstream end (12).

3. A member according to claim 1 or 2,
c h a r a c t e r i z e d in
that the material thickness of the cooling channel wall is larger in a downstream end (13) of the channel than in an upstream end (12).

4. A member according to any one of claims 1-3,
c h a r a c t e r i z e d in
that each cooling channel (11) is formed by a sheet metal profile (18).

5. A member according to any one of claims 1-3, c h a r a c t e r i z e d in that the cooling channels are formed by seamless tubes (15).

6. A member according to any one of claims 1-5, c h a r a c t e r i z e d in that the cooling channels (11) are mounted with mutual contact at the inlet end (12) of the member, and with mutual distances at the outlet end (13) of the member.

7. A member according to claim 6, c h a r a c t e r i z e d in that the distance between two adjacent cooling channels at the outlet end (13) of the member (10) is filled with an insulating material (17).

8. A member according to claim 6, c h a r a c t e r i z e d in that the distance between two adjacent cooling channels at the outlet end (13) of the member (10) is filled with a thermally conductive material (17).

9. A method for manufacturing a liquid fuel rocket engine member (10) forming a body of revolution having an axis of revolution and a cross section which varies in diameter along said axis, and having a wall structure comprising a plurality of cooling channels (11), c h a r a c t e r i z e d in the steps of

forming a sheet metal wall (14) having a wall section corresponding to the desired member section,

providing a plurality of channel members (15; 18), and

attaching the channel members (15; 18) to the inside of the sheet metal wall (14).

10. A method according to claim 9, characterized in the step of attaching the cooling channels (11) to the sheet metal wall (14) by welding from the outside of the wall.

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Huvudfaxen Kassan

ABSTRACT

The invention relates to a liquid fuel rocket engine member (10). The member forms a body of revolution having an axis of revolution and a cross section that varies in diameter along said axis. The wall structure comprises a plurality of cooling channels (11). The outside of the wall structure includes a continuos sheet metal wall (14). The cooling channels (11) are longitudinally attached to the inside of the sheet metal wall. A method for manufacturing the rocket engine member (10) includes the steps of forming a sheet metal wall (14) having a wall section corresponding to the desired nozzle section, providing a plurality of channel members (15; 18), and attaching the channel members (15; 18) to the inside of the sheet metal wall (14).

(Fig. 2)

Fig.1

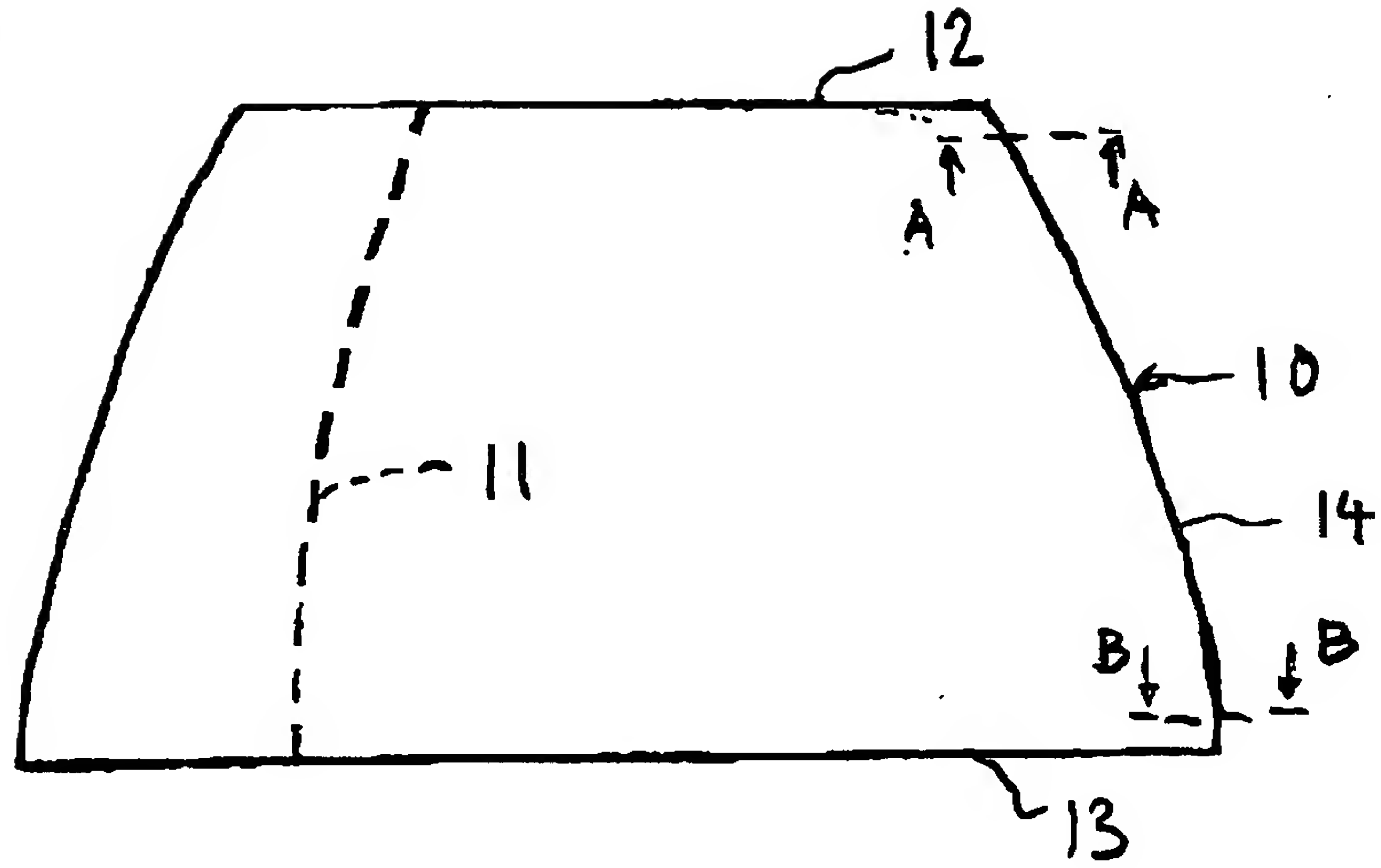

Fig.2

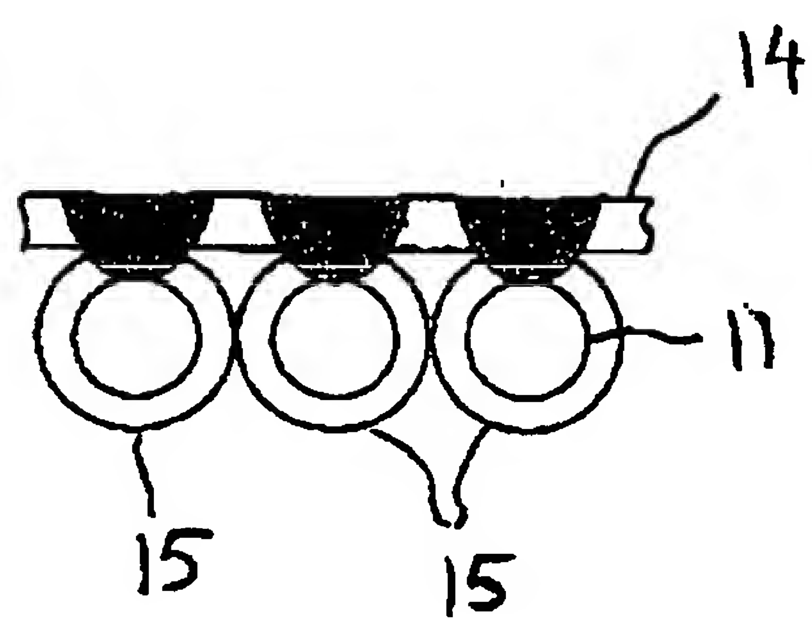

Fig.3

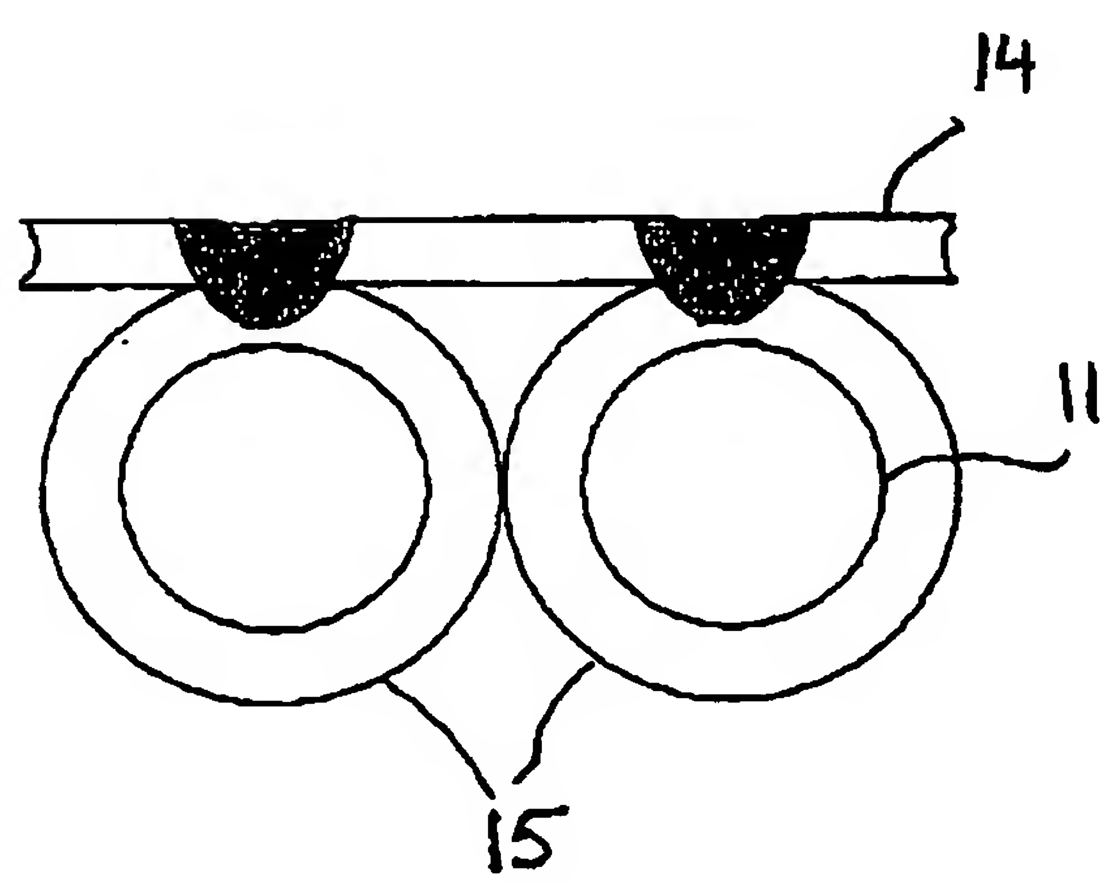

Fig. 4

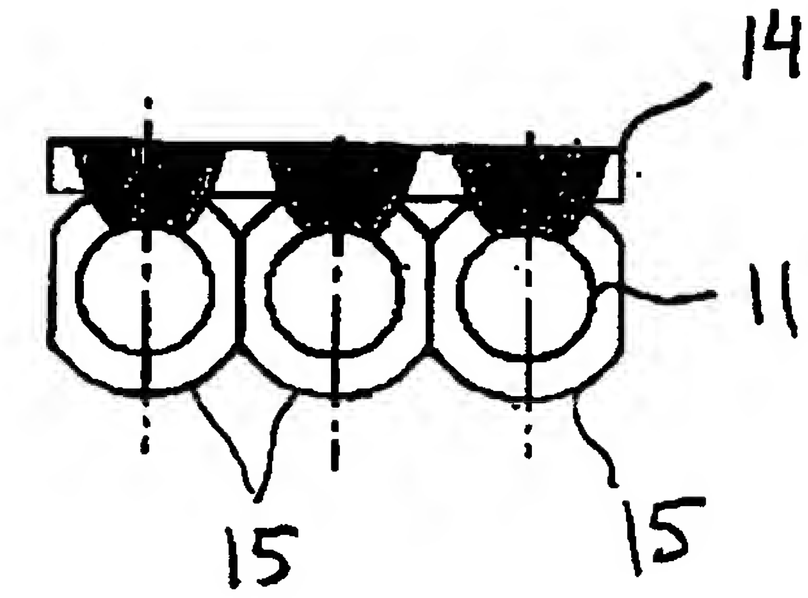

Fig. 5

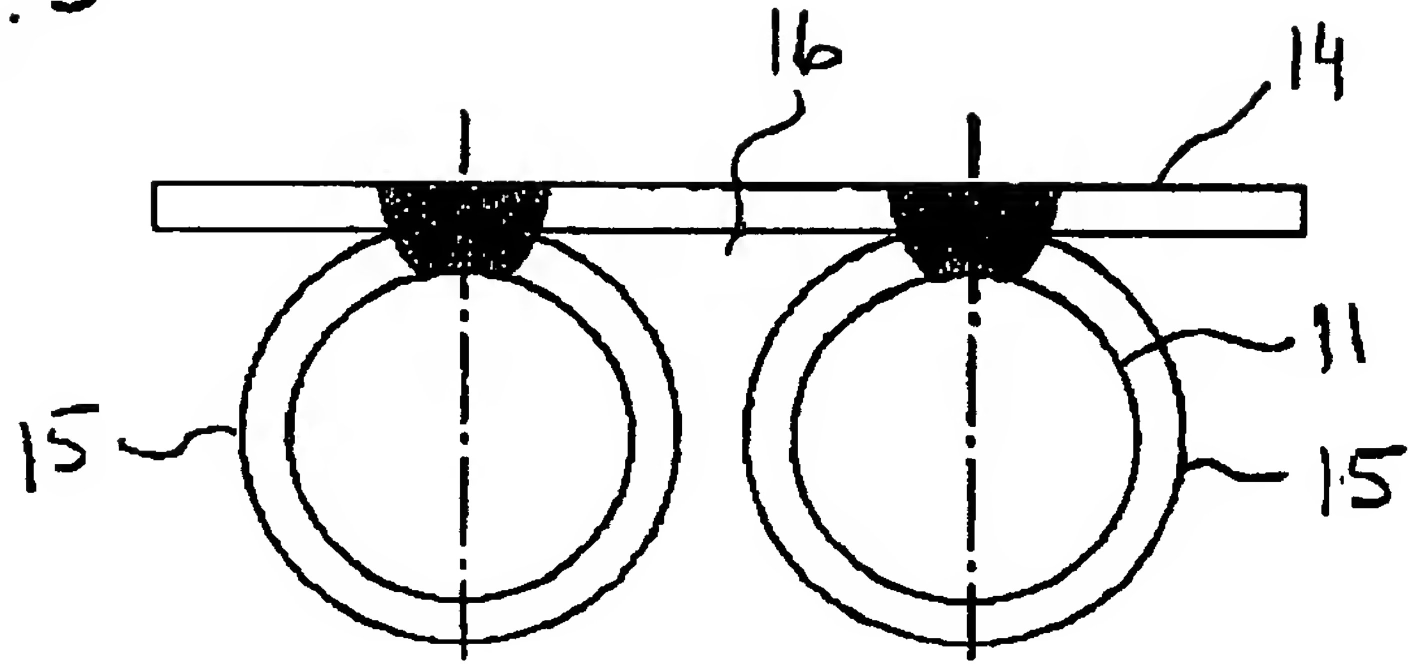

Fig. 6

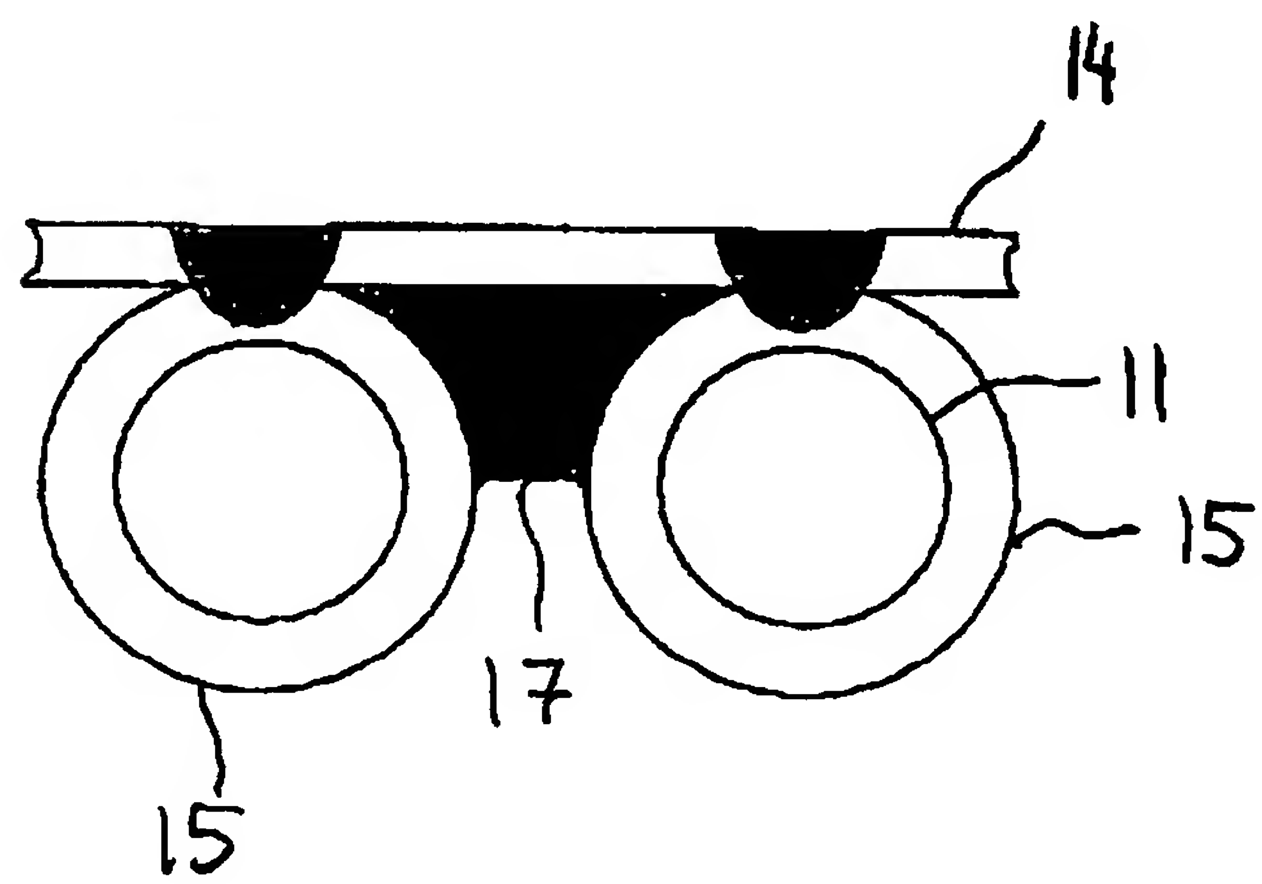

Fig. 7

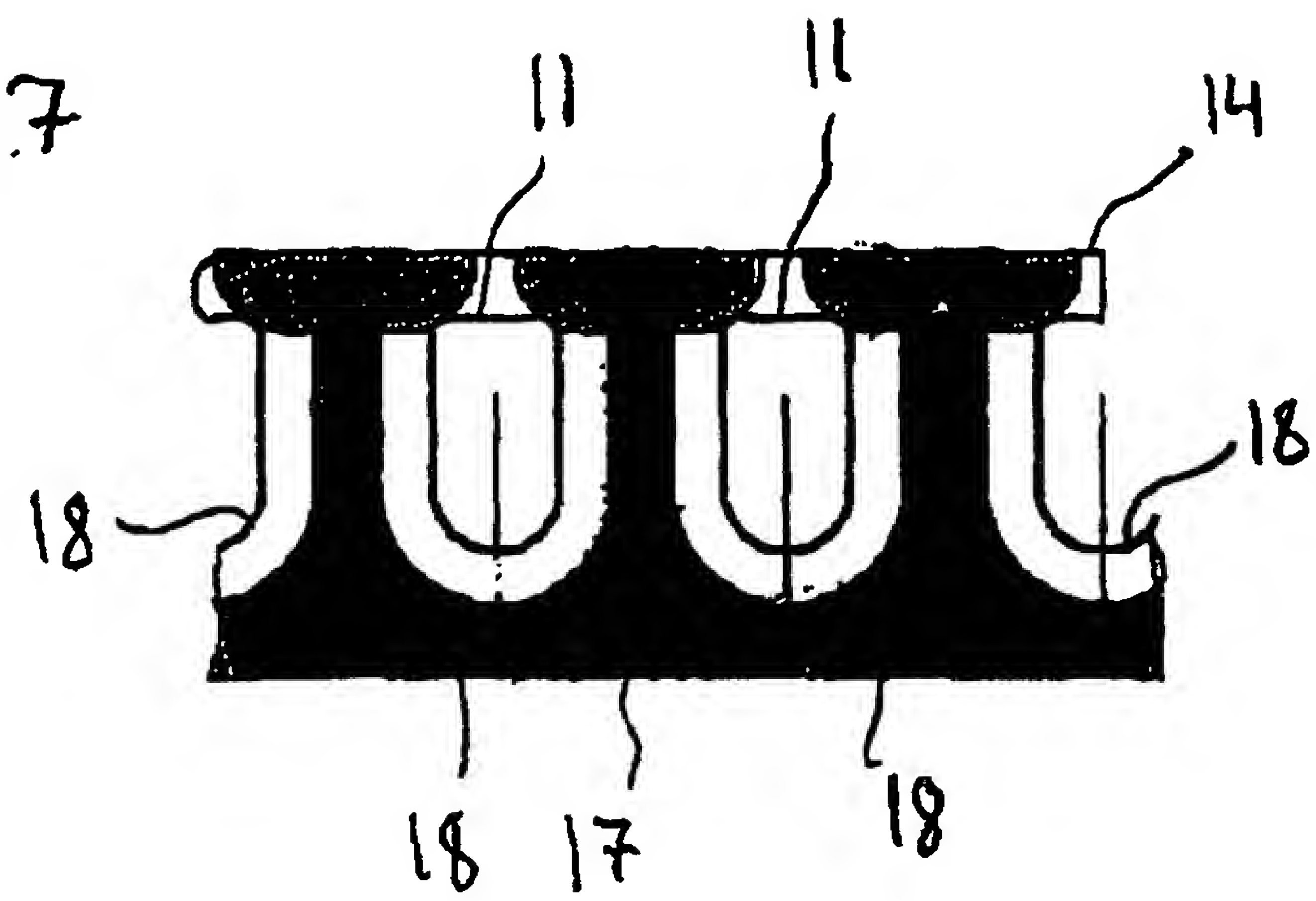

Fig. 8